

Factors Influencing Rocky Mountain Tailed Frog (*Ascaphus montanus*) Distribution and Abundance

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February 2006

**Progress Report for Summer 2005:
Montana Fish, Wildlife, and Parks and Potlatch Corporation**

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ABSTRACT

The goal of this study is to examine the factors influencing the distribution and abundance of Rocky Mountain tailed frog tadpoles. Nearly all the research evaluating the influence of physical habitat variables and food on tadpoles has focused on the coastal tailed frog. Few studies have evaluated the spatial context of these limiting factors with regard to Ascahpid tadpole occurrence and age class distribution. To determine what factors influenced tadpole occurrence and abundance we addressed four questions (see Jones et al. 2005) relating to tadpole distribution in a stream network.

Between June 28th and August 10th, 2005, we conducted this study in two different watersheds: the South Fork of the Flathead River watershed in northwestern Montana, and Mica Creek watershed in northern Idaho. In each watershed, we sampled tailed frog tadpoles in 5 randomly selected 1 m transect belts across ≥ 24 stream reaches, starting in the headwaters and continuing to the largest stream order in the watershed. Environmental measurements at each transect belt included distance upstream from tributary mouth, temperature, aspect, substrate composition and embeddedness, large woody debris, benthic organic matter, and percent undercut bank. Environmental measurements at each reach included aspect, substrate heterogeneity, and discharge. In a minimum of 14 transect belts in each stream, we sampled 5 rocks for periphyton biomass. Additionally, at each transect we noted the presence of any fish species.

Statistical analyses to date have included linear regressions of tadpole biomass and density and ANOVA of tadpole occurrence. Future analyses will include logistical regression of occurrence data and geostatistical analysis of our stream networks.

To date, our results have focused exclusively on the channel unit (pool/riffle) and reach scales. Our use of the three-pass depletion method demonstrates that a single pass effectively captures 81% of all animals within a transect belt. Transect belts in Mica Creek had a decrease in tadpole occurrence with increasing levels of chlorophyll-*a*, which differed from Youngs Creek, which had an increase in tadpole occurrence with increasing chlorophyll-*a*. Fish presence did not appear to decrease tadpole occurrence in either system. The density and biomass estimates obtained from the methods described and incorporated by Lohman (2002) were significantly greater than the estimates obtained from our methods. Based on our results, we hypothesize that tadpoles exhibit niche shifts at different developmental stages and spatial scales.

INTRODUCTION

Tailed frogs (*Ascaphus* spp.) are important components of headwater stream ecosystems of the Pacific Northwest and Rocky Mountains. Tailed frog tadpoles play important functional roles as benthic grazers and prey in stream ecosystems (Kiffney and Richardson 2001, Rosenfeld 1997, Lamberti et al. 1992, Corn and Bury 1989). They commonly comprise the highest herbivore density and biomass in these systems (Hawkins et al. 1988); tailed frog tadpole biomass has been reported to be an order of magnitude greater than trout biomass in some headwater streams of the Pacific Northwest (Corn and Bury 1989).

Understanding the environmental variables that influence the development of amphibian larvae is of critical importance when evaluating the future survival and success of an amphibian population. Given that the larval stage of tailed frogs may last upwards of three years (Figure 1 and 2; Metter 1964), larvae are locally abundant in appropriate habitats (Bury 1988, Hawkins et al. 1988, Corn and Bury 1989), and larvae are sensitive to environmental perturbation (Welsh and Olliver 1998, Kremsater et al. 2003), tailed frog tadpoles are excellent study organisms for evaluating the effect of environmental variables on organism distribution and abundance.

Research regarding the role of *Ascaphus* spp. in the structure and function of stream ecosystems has generally focused on the coastal tailed frog (*Ascaphus truei*). Although both species of *Ascaphus* are believed to have similar habitat and dietary requirements, few studies have evaluated the factors limiting the Rocky Mountain tailed frog's distribution and abundance. Research providing a foundation for evaluating the ecological role of *Ascaphus* tadpoles in a stream system exists for the coastal tailed frog

(Hawkins et al. 1988, Diller and Wallace 1999), but does not for the Rocky Mountain tailed frog.

Few studies regarding *Ascaphus* spp. have addressed differences in age class structure in their analysis of distribution and abundance, and even fewer studies have evaluated the ecological differences between age classes in stream networks. While most stream dwelling tadpoles metamorphose in a single season, *Ascaphus* tadpoles can require three years to complete metamorphosis. Similar to aquatic macroinvertebrates, shifts in ontogeny may result in niche shifts with tadpoles. Despite a poor understanding of their ecological roles, most stream dwelling tadpoles are widely regarded as grazers or detritivores, (McDiarmid and Altig 1999). Studies concerning stream dwelling tadpoles suggest that tadpole growth rates at the channel unit (pool/riffle) scale are limited by food (Brown 1990, Mallory and Richardson 2005, Whiles et al. 2006) and that tadpoles may influence ecosystem structure and function by altering algal communities (Kupferberg 1997, Ranvestel et al. 2004, Whiles et al. 2006).

Concerning the factors that control or limit tailed frog tadpole distribution and abundance, most studies to date have focused on relationships at the channel unit and reach scales. Only a handful of studies have evaluated factors limiting amphibian distribution and abundance at the landscape level. Diller and Wallace (1999) evaluated the factors influencing coastal tailed frogs across channel unit, reach, and landscape scales. Concerning the Rocky Mountain tailed frog, no studies have evaluated the environmental variables that may control or limit tadpoles across a range of spatial scales.

This study focuses on evaluating the factors influencing Rocky Mountain tailed frog abundance and distribution in stream networks. In our proposal (Jones et al. 2005),

we proposed the following questions: (1) How do tadpole occurrence, abundance, and age class structure vary throughout a stream network, specifically from headwater to larger order streams? (2) What are the abiotic factors influencing tadpole occurrence and abundance? (3) What are the biotic factors influencing tadpole occurrence and abundance? (4) How do distribution and abundance patterns in an experimentally manipulated forest watershed compare to a nearby wilderness watershed? In this report, answer several of the proposed questions while providing suggestive evidence for our overarching hypothesis that tadpoles may exhibit niche (i.e., diet, habitat) shifts at different developmental stages and spatial scales.

HYPOTHESES

Based on our proposed questions, we collected data across two stream networks and have refined our hypotheses to further investigate our overarching hypothesis during our second field season. Our hypotheses in order of proposed questions are:

- (1) *Different larval stages are more abundant in different portions of the stream network, with older tadpoles located further downstream and younger tadpoles located further upstream.*
- (2) *The relationship between tadpole abundance and physical habitat factors changes with spatial scale.*
- (3) *The relationship between tadpole abundance and biotic factors (i.e., food, predation) changes with spatial scale.*
- (4) *Factors limiting tadpole distribution and abundance vary between watersheds in different regions due to a combination of inherent biogeoclimatic differences and land-use practices.*

Our first hypothesis states that as stream order increases, a higher relative abundance of older age classes should occur. Although adults exhibit high site fidelity (Metter 1964, Daugherty and Sheldon 1982), newly metamorphosed frogs move upstream prior to breeding (Landreth and Ferguson 1967, Hunter 1998, R. B. Bury USGS Forest and Rangeland Ecosystem Science Center, personal communication) and tadpoles presumably drift downstream over the course of their three-year larval stage (Hunter 1998). This background in combination with preliminary observations has led us to reason that older age classes should be more abundant in intermediate-size streams (2nd–3rd order) due to their extended exposure (up to 3 years) to drift in the fast moving mountain headwater streams.

Our second hypothesis states that increased tadpole productivity is associated with a suite of habitat characteristics including: lower annual temperatures, larger sized and loosely embedded substratum, overall higher stream gradient, and higher elevations. Lower annual temperatures and discharge are most strongly associated with differences in tadpole abundance at the broadest spatial scale, while higher gradients and lower heat loads associated with stream aspect influence abundance at the reach scale. Larger sized, loosely embedded substrate influences tadpole abundance at the smallest spatial scale measured, channel unit. We have used the results from several *A. truei* studies to guide our selection of the physical habitat features we measured in the field (e.g., Bury and Corn 1988, Corn and Bury 1989, Welsh and Ollivier 1998, Adams and Frissell 2001, Wahbe and Bunnell 2003, Wahbe et al. 2004).

Our third hypothesis states that the relationship between tadpole occurrence and abundance varies with biotic factors (food and predation) across spatial scales. We base

our third hypothesis on the idea that grazers in shaded, oligotrophic streams can become food-limited (Hart 1987; Hill and Knight 1987; Lamberti and Resh 1985). At the channel –unit (e.g. riffle/pool) scale, we hypothesize that tadpole biomass is positively associated with higher chlorophyll *a* content and lower relative ash free dry mass (AFDM). Tailed frog tadpoles are benthic periphyton grazers (Metter 1964). Primary production by algae (measured as chlorophyll *a*: a component of periphyton) and periphyton (measured as the ash-free dry mass on stone surfaces) provides a key resource to stream food webs (Minshall 1978) and can be limited by both physical habitat features and grazing (Mallory and Richardson 2005). The streams inhabited by tailed frogs are commonly associated with heavily forested riparian areas (Metter 1964, Bury and Corn 1988, Bury et al. 1991), and streams containing filamentous algae generally lack tadpoles (Kupferberg 1996).

Also at the channel unit scale, we hypothesize that the presence of fish species (e.g. sculpin, bulltrout, brook trout) directly influences tadpole occurrence. *In vitro* experiments have confirmed that sculpin and trout prey on tadpoles (Feminella and Hawkins 1994), but few studies have investigated the in stream effects of fish on tadpole distribution and occurrence. Feminella and Hawkins (1994) demonstrated that the presence of chemical cues from non-native brook trout (*Salvelinus fontinalis*) reduced tadpole activity more than native sculpin (*Cottus* spp.) and cutthroat trout (*Salmo clarki*). The increased tadpole activity in the presence of chemical cues from native fish may explain why tadpoles are found in small order stream reaches occupied by both sculpin and native salmonids.

By studying two nearby, but inherently different (i.e., varying in geology,

elevation, precipitation, and vegetation), watersheds, we anticipate that changes will occur in the factors influencing Rocky Mountain tailed frog tadpole distribution and abundance in a stream network. Regarding our final question, we hypothesize that in a stream with decreased biomass of food, food may control the distribution and abundance of tadpoles, while physical habitat features will control distribution in a watershed with increased food availability. The abiotic and biotic factors influencing an organism's distribution may be mediated by the physical habitat template of climate (e.g., annual precipitation, temperature), geology, and vegetation, as well as human-imposed landscape change. Annual precipitation, geology, elevation, vegetation, and management practices indeed influence *Ascapus* spp. distribution and abundance (Metter 1967, Bury and Corn 1988, Diller and Wallace 1999, Dupuis and Steventon 1999). Comparisons between watersheds with comparable tadpole densities, but inherently different physical habitat characteristics, may reveal a difference in the factors that control or limit the distribution and abundance of tadpoles in a stream network.

IMPORTANCE

Our research project is among the first to evaluate *Ascapus* tadpole distribution, biomass, and age structure within a watershed and throughout the network of a stream. This study is among the first to evaluate the role of stream amphibians in naturally occurring trophic interactions and what roles differing life stages serve within such interactions. By evaluating entire stream networks, we increase our power to detect patterns at multiple spatial scales. Our study is further strengthened by evaluating a combination of limiting factors (i.e., food and physical habitat features) across multiple spatial scales. By evaluating the influence of limiting factors at several spatial scales,

patterns may emerge that are unrelated to our hypotheses. Our evaluation of two inherently different streams of historically high tadpole density also adds strength to our study. We anticipate uncovering how factors limiting this species may vary across geographic regions.

Our evaluation of tadpoles in a stream network facilitates monitoring efforts of this headwater stream indicator. Further, evaluating the use of stream networks by tailed frog tadpoles provides a spatial context for interpreting previous study results and help focus conservation and habitat management efforts across multiple spatial scales. If used with data collected from adjacent road-less watersheds, this research also provides a foundation for evaluating the impacts timber harvest and associated activities have on Rocky Mountain tailed frogs. Though several studies have evaluated the effects of timber harvest on tailed frogs, our results place these studies in a spatial context and provide a framework for future studies evaluating watersheds impacted by logging and associated activities basis.

METHODS

Study Areas: We sampled streams in two study areas: Youngs Creek, a tributary of the South Fork of the Flathead River in Montana, and Mica Creek, a tributary of the St. Joe River in northern Idaho (Figure 3). Youngs and Mica creeks vary slightly in their latitude. Youngs Creek is located in the western Canadian Rockies ecoregion, while Mica Creek is located in northern Rocky Mountain ecoregion (Omernick 1987; Table 1). Slight overlap exists between elevation ranges in Youngs and Mica creek. The creeks differ in management practices, size (i.e., stream order), origin, vegetation, and annual precipitation (Table 1).

Youngs Creek, a 4th order stream, emerges from glacier fed lakes near 2100 m elevation. Youngs Creek forms the southwestern headwater of the South Fork of the Flathead River. Flowing over 24 km through the Bob Marshall Wilderness Area, the Youngs Creek drainage is typified by ponderosa pine (*Pinus ponderosa*) and Douglas fir (*Pseudotsuga menziesii*) forests. The Bob Marshall Wilderness Area, designated in 1964, encompasses over 1 million acres of wilderness spanning the continental divide. Annual precipitation averages 100 cm per year.

In contrast, Mica Creek forms from four headwater springs, located in the St. Joe drainage of northern Idaho. As a 3rd order tributary, Mica Creek flows over 23 km, losing over 700 m before its confluence with the St. Joe River (Lohman 2002). Western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), and grand fir (*Abies grandis*) typify the vegetation found in the Mica Creek watershed. With an average annual precipitation of 140 cm, the Mica Creek drainage exceeds the annual precipitation of Youngs Creek.

Potlatch Corporation manages a portion of Mica Creek as an experimental watershed. In 1990, Potlatch Corporation initiated a project to evaluate the effects of modern forestry practices on stream resources. In the Mica Creek experimental watershed, Potlatch constructed seven flumes in a nested sampling design to trace the downstream effects of treatments (timber harvest and associated road building) on sedimentation and temperature (McGreer et al. 1995).

Study Design: We located stream valley segments using topographic maps. Integrating landforms and fluvial features of valley morphology with channel relief, shape, and

dimension, we numbered each stream segments. Based on the average size of the stream segments and logistical constraints we stratified and weighted our sampling design by stream order. We randomly placed reaches in our defined segments and stream orders (Figure 4). We sampled 27 and 24 stream reaches (250 meters in length) in Youngs and Mica creek, respectively, from June 30 to August 8, 2005. The 27 randomly selected reaches spanned 24 kilometers of Youngs Creek from its headwaters to confluence with Hahn Creek. In Youngs Creek drainage, our sampling included two major tributaries (2nd order) and four randomly selected small tributaries (1st order): Marshall, Babcock, Otter, Hahn, Boulder, and Ross creeks. Using previously established study reaches in Mica Creek (McGreer et al. 1995) and additional randomly selected reaches, we sampled 28 reaches spanning 14 kilometers of stream from its headwaters to Mica Meadows.

Our sampling unit consisted of a subset of 5 randomly selected transect belts (1m in length) nested within a randomly distributed study reach. To adequately represent tadpole abundance in reaches, we sampled 5, 1 m long, transect belts randomly placed along 250m reaches (based on previous sampling in Idaho and Montana; Bury et al. 2002, D.S. Pilliod, USGS Rocky Mountain Research Center, personal communication). We identified locations for transect belts (Figure 5a) by unrolling a tape measure from the downstream edge of a previous transect (or start of reach, indicated by a randomly designated reference point or the presence of a flume) to the downstream edge of the next randomly placed transect upstream. Additionally, belt locations were georeferenced using a global positioning system (GPS) unit (as measured in UTM, NAD27; Garmin™ eTrex, Kansas, USA).

As a side project, we compared sampling methods in Mica Creek as a means of

evaluating the effects of timber harvest on tailed frogs. Using stream segments sampled by Lohman (2002), we sampled 4 flumes and evaluate which method reflects most accurately the relative abundance of tadpoles within the experimental watershed. The evaluation of sampling methods will assist Potlatch in determining which sampling techniques adequately depict tadpole abundance along impacted stream segments and assist biologists in determining whether before and after comparisons are possible using methods currently employed.

During summer 2005, our sampling schedule consisted of four work periods, beginning June 28 and ending August 10. Each period consisted of ten days, with 8-12 work hours each day. Work during periods of early morning and evening hours were commonplace on data collection trips. Four days for personal time and re-supply followed each work period. In addition to summer work, two trips into Youngs and Mica creek occurred during August 13-16 and October 15-18, 2005, respectively; during these trips, we launched or retrieved and re-launched tidbit temperature data loggers (HOBO Pendant™ Loggers, Onset, Pocasset, MA).

Environmental Variables: At each transect belt, we measured and recorded a suite of physical stream features (Figure 5a). These included: aspect, stream thalweg temperature (at time of sampling and continuously monitored by in stream temperature loggers), ambient air temperature at 1 m on stream bank, wetted channel width, stream depth profile, substrate composition, substrate embeddedness, abundance of large woody debris and benthic organic matter, presence of undercut banks, percent cover, and reach classification. Appendix A contains a list and description of each habitat variable.

Periphyton Measurements: In a subset of randomly selected reaches, we selected 16 transect belts in Youngs Creek, which consisted of 80 rocks and spanned approximately 20 km of Youngs Creek, between August 1st and 8th, 2006 (Table 2). In Mica Creek, we sampled 14 transects (70 rocks), spanning 12 km of stream, between July 25th and 29th, 2006. For both streams, we haphazardly sampled 5 rocks, which were selected for periphyton sampling on the basis of size, shape, and location in the stream. Periphyton sampling followed the methods described by Davis et al. (2001). All samples were frozen until October and November 2005, when we processed them at the Stream Ecology Center and Center for Ecological Research and Education laboratories at Idaho State University. We determined chlorophyll *a* biomass, AFDM, and autotrophic index (AI) ratio of each sample using the methods described in AHPA (1995). We estimated an AI ($AI = (AFDM)/(chlorophyll\ a)$) for each sample to compare differences in primary productivity between our sampling locations (Clesceri et al. 1998). Values that exceed an AI of 200 indicate heterotrophic conditions or poor water quality.

Tailed Frog Measurements: We sampled tailed frog tadpoles by working upstream of two hand-held D-frame nets (0.8 mm mesh; Figure 5b; Bury et al. 2002). In each transect we lifted large cover items and kicked through the substrate to facilitate the capture of tadpoles (Figure 5c). To determine the effectiveness of our sampling design, we randomly selected a minimum of three transect belts in each stream and performed three-pass depletion sampling. This consisted of sampling one transect belt three times with equal amount of effort (measured in time); with each pass we removed and counted all

animals; following the third pass, we released all the animals. We divided the number of animals captured in each pass by the total number of animals captured for all three passes and used this percentage as an estimate for comparing the efficiency of our technique.

We segregated tadpoles by age classes based on developmental stage (Figure 1 and 2; Metter 1964, 1967, Brown 1990, Lohman 2002) using 100 ml whirlpaks™ and nylon buckets. To determine total density and biomass of each age class, we divided the total number and en masse weight of each age class by the area sampled.

Incidental mortalities rarely exceeded 2% of the tadpoles captured in a transect belt. When possible, we preserved incidental mortalities in 70% EtOH solution for future laboratory analysis and deposition at Idaho Museum of Natural History (Appendix B). We did not encounter adult tailed frog or fish mortalities; to confirm fish species, photographs were taken when possible. We monitored and measured development of an egg mass for 24 days with a digital camera (Figure 6; Pentax™ Optio WP 5.0 Mega-pixel, Colorado, USA). Additionally, we documented tadpole life stages (Figure 2), including metamorphosis, tadpole underwater behavior (cover photo), and morphological variations in adults throughout the sampling season with a digital camera. Finally, we documented fish predation events when opportunities arose (Figure 7).

Statistical Analyses: We used statistical analyses to test hypotheses and a GIS to explore and identify spatial patterns at multiple scales (i.e., reach, stream, and watershed). For this report, we first constructed a correlation matrix to explore possible associations between our predictor variables. The predictor variables we used were not correlated with one another (i.e., maintained independence), so our preliminary analysis of tadpole

biomass and density consisted of simple linear regression models based on the three *a priori* hypotheses with specified independent predictor variables (both food and physical habitat features). For example, we used regression models to explore the relationships between PAR, periphyton composition, and tadpole biomass/density along the stream network. Using ANOVA, we analyzed the food and physical habitat features that we had predicted would influence tadpole occurrence. We also used ANOVA to compare the effectiveness of our sampling design through the use of three-pass depletion sampling. Additionally, we used a linear regression and ANOVA to compare our methods with previously established methods in Mica Creek (Lohman 2002). We sampled the 1 m transect belts we compared with Lohman (2002) in close spatial (< 10 m) and temporal (< 8 days) proximity of Lohman's sampled reach. Before the next field season, tadpole density and biomass will be analyzed using ANCOVA, and tadpole occurrence will be analyzed using logistic regression. We will further evaluate our data using statistical analyses that account for non-independent, spatially autocorrelated data (i.e., sites occurring within stream networks; Ganio et al. 2005).

RESULTS & DISCUSSION

Sampling Efficiency: We evaluated sampling methods between streams through the three-pass depletion sampling method. Our sampling effort at each transect belt averaged 12.6 minutes. Our use of the three-pass depletion sampling method demonstrates that a single pass effectively captures 81% of all animals within a transect belt ($N=11$, $DF=9$, $R^2=0.962$, $p<0.001$; Figure 8). In comparison to estimates of efficiency in fish depletion methods, our single pass appears to estimate tadpole abundance at a relatively higher percentage than those employed in fish studies (Peterson et al. 2004).

Spatial Scaling: In Youngs Creek drainage the spatial extent of our sampling design exceeded 50 km of stream length. Although our spatial extent was larger in Youngs Creek than in Mica Creek (20 km), our sampling density at the reach scale was slightly smaller in Youngs Creek than in Mica Creek. The sampling density was estimated by adding the total length of the reaches sampled (250 m/reach) and dividing that number by the spatial extent, this number when multiplied by 100 gives a percentage of the total drainage that was covered at the reach scale. In Mica Creek we covered approximately 30% of the total stream network, which doubled the density of sampled in Youngs Creek (14%).

Environmental Variables: A larger stream, Youngs Creek exhibited the highest and most variable discharge. At transect belts, Youngs Creek had a minimum discharge of 0.004 m³/s, a maximum of 3.21 m³/s, and a mean of 0.94 m³/s, while Mica Creek measurements ranged from a minimum of 0.01 m³/s to a maximum of 2.01 m³/s, with a mean of 0.38 m³/s (Table 2). The higher variation and mean in discharge rates for Youngs Creek appears to be an artifact of our selection of sampling locations. In both streams, discharge decreased with distance upstream (Youngs: $r^2 = 0.22$, $P = 0.002$; Mica: $r^2 = 0.61$, $P < 0.001$).

Distance upstream influenced other environmental variables within both stream systems. The amount of available PAR decreased with distance upstream (Figure 9). In Youngs Creek, mean water temperatures taken at each transect belt decreased slightly with movement upstream, while water temperatures in Mica Creek decreased

dramatically with distance upstream (Figure 10). Differences observed in temperature changes within the watershed may also be an artifact of our sampling design; this will be evaluated in the analysis of our in stream temperature loggers next season. Other habitat variables will be analyzed before the 2006 summer field season.

Periphyton: Mica Creek exceeded Youngs Creek in chlorophyll-*a* content by an order of magnitude (Table 2), indicating a higher standing crop of primary producers in Mica Creek. Mica Creek also had a higher total periphyton biomass, as indicated by AFDM, when compared to Youngs Creek (Table 2; $P < 0.001$). Primary producer biomass did not appear to be associated with total periphyton biomass in either stream, indicating that the algal component of the periphyton community may not comprise the bulk of the AFDM. Primary producer biomass in Youngs and Mica creeks did not appear to be associated with PAR, but total periphyton biomass appeared to decrease with increasing PAR in Mica Creek (Mica: $y = -0.0218x + 15.713$, $r^2 = 0.467$, $P = 0.021$). Distance upstream and discharge did not appear to influence primary producer or total periphyton biomass.

Tailed Frogs: Across the 27 reaches (135 transect belts) sampled in Youngs Creek, we captured 1,399 tadpoles in 25 reaches (99 transect belts), representing a mean biomass of $1.67 \text{ g/m}^2 (\pm 0.24)$ and density of $2.35 \text{ individuals/m}^2 (\pm 0.32)$ (Table 3). In two transects, we observed egg masses, representing 182 eggs. Our observation of egg masses in Youngs Creek represents one of the first sightings of egg deposition in the Bob Marshall Wilderness Area. Across 24 reaches (120 transect belts) sampled in Mica

Creek, we captured 737 tadpoles in 21 reaches (80 transect belts), representing a mean biomass of 1.98 g/m² (± 0.27) and density of 3.08 individuals/m² (± 0.45). This number in Mica Creek represents 53% of total tadpoles captured in Youngs Creek. We observed three egg masses in Mica Creek, representing approximately 433 eggs in three transects. In Mica Creek, the temperatures recorded for one egg mass completing late stages of Gosner development measured 19.0°C, which exceeded the proposed thermal tolerance of 18.5°C for embryonic development (Adams and Frissell 2001, Karraker et al 2006). Our monitoring efforts appear to be among the first to demonstrate that egg masses can withstand the disturbance of sampling if attachment rocks are carefully placed back into the stream (Figure 6). Additionally, our observation appears to be the first to document *in vivo* development of *Ascaphus* egg masses through the use of a digital camera.

Tadpole distribution patterns differed by age class both within and between the two different stream networks studied. In Youngs Creek, tadpoles occurred more frequently with increasing distance upstream (ANOVA N=39, DF=38, $P < 0.0001$). In Mica Creek, tadpoles occurred more uniformly across the stream network. Trends in the tadpole density appeared in both creeks, tadpole density increased with increasing distance upstream (Youngs: $P = 0.002$; Mica: $P = 0.122$), while biomass estimates increased much less than density estimates in Youngs Creek ($P = 0.086$) and remained relatively constant in Mica Creek ($P = 0.876$). Tadpoles in the 3rd year age class were observed in higher densities across lower reaches in Mica Creek, while 1st year animals were observed in greater abundance in upstream sites in both creeks (Figure 11 and 12). We observed a trend of higher 1st year tadpole densities than 3rd year in Youngs and Mica creek (Youngs: ANOVA N = 261, DF = 260, $r^2=0.01$, $P = 0.10$; Mica: ANOVA N = 221,

DF = 220, $r^2 = 0.05$, $P = 0.0007$) and the opposite trend with biomass, as 3rd year tadpoles occurred in an overall higher biomass than 1st year tadpoles (Youngs: ANOVA: N = 261, DF = 260, $r^2=0.04$, $P = 0.0004$; Mica: ANOVA N = 221, DF = 220, $r^2 = 0.013$, $P = 0.090$).

The association between tailed frog tadpoles and periphyton appeared to vary with spatial scale within a network, but also seemed to differ between the two study watersheds. We cannot separate transect belt and reach level analysis for data collected this season due to our small sample size. At the transect belt and reach scale, primary producer biomass showed the same patterns within a stream, but differed between streams (Figure 13). In Mica Creek, tadpole biomass decreased with increasing levels of primary producer biomass. In Youngs Creek, which had lower levels of chlorophyll-*a*, tadpole biomass appeared to increase with primary producer biomass. Total periphyton biomass (AFDM) was not associated with tadpole biomass or density. For both streams at the transect belt and reach scale, tadpole density increased with distance upstream.

An evaluation of tadpole occurrence and fish presence at the transect belt and reach scale revealed similar trends, indicating that tadpoles occupy channel units and reaches despite fish presence (Table 4). In Youngs Creek, we observed fish in 19 transect belts (15%) and 13 reaches (50%). All of the fish we observed were salmonids. We observed no sculpin in the transect belts. Of the 19 transects and 13 reaches in which fish were observed, 14 (74%) and 12 (92%) contained amphibians. Of the 61 transect belts and 20 reaches in which fish were observed in Mica Creek, 51 transect belts (83%) and 20 reaches (83%) had fish and amphibians present in the same transect or reach. Of

the 61 transects in which fish were observed, 52 (85%) were mottled sculpin (*Cottus beldingi*) and 11 (18%) were brook trout (*Salvelinus fontinalis*; Figure 7).

The density and biomass estimates obtained from the methods described and incorporated by Lohman (2002) were greater than the estimates obtained from the methods we used (Figure 14 and 15). For all reaches, Lohman sampled one transect approximating 10 m in length (an average area of $14.65 \text{ m}^2 \pm 1.27$). We used two alternative approaches to compare with Lohman (2002). We randomly sampled 10 and 15 1 m transect belts across 500 and 1000 m of stream, respectively. The random transect belts we sampled averaged $2.05 \text{ m}^2 (\pm 0.21)$ in area. Statistical comparisons were not attempted for the Lohman (2002) methods due to lack of transect belt replication at each flume. Despite the higher abundance observed at the smaller, 10 m belt scale (Lohman 2002), we observed no difference between the results of our sampling efforts at three of four sites using the 500 m ($N_{\text{transect}} = 15$) and 1000 m ($N_{\text{transect}} = 10$) sampling design (Figure 16). Our results confirm that despite the patchy distribution of tadpoles in some streams, larvae may be locally abundant in appropriate habitats (Bury 1988, Hawkins et al. 1988, Corn and Bury 1989).

SIGNIFICANCE & FUTURE DIRECTIONS

The results from our analyses demonstrate that inherent differences between streams may modify factors influencing tadpole distribution and abundance. Addressing the effects of timber harvest on tailed frogs by comparing two inherently different watersheds adds further complexity to disentangling the factors that limit and control tadpole distribution and abundance at multiple scales. Without additional, adjacent

watersheds for use in comparing the effects of timber harvest, we can only speculate what the effects of timber harvest are on tailed frogs. Even with the addition of adjacent watersheds, the design of the Mica Creek experimental watershed may not lend itself to statistical comparisons between timber harvest treatments, due to the lack of replication for each treatment. Inherent differences between the treatment streams (e.g. aspect, gradient) may override our ability to determine the effects of timber harvest on treatment and control groups. Further, areas of historically high tadpole density may remain less affected if additional management action is taken (e.g., buffer strip retention). The spatial extent of sampling appears to directly influence abundance estimates. Additionally, sampling methods should attempt to adequately reflect the variation in abundance and distribution along the entire treatment and the cumulative effects downstream. Combining multiple sampling methods, which incorporate abundance and distribution estimates across the stream network (large extent) and intensive reach scale (high resolution) abundance estimates, may assist managers in determining how tadpoles are affected by timber activities across multiple spatial scales.

We plan on working to raise additional funds to allow us to expand our sample size at the network scale in Mica Creek. Additionally, we plan on increasing the number of periphyton samples taken at each reach in both watersheds. This year we will also conduct underwater surveys (via snorkeling) in large order reaches to assist in the analysis of the factors influencing the occurrence of tadpoles at the reach and segment level.

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TABLES

Table 1. Habitat characteristics for Mica Creek, Idaho, and Youngs Creek Montana.

Characteristics	Mica Creek	Youngs Creek
Elevation range (m)	1725-975	2200-1400
Ecoregion	Northern Rockies	Western Canadian Rockies
Rainfall (cm/year)	140 cm	40-90 cm
Latitude range (UTM Northing)	5220000 m	5240000 m

Table 2. Mean values (\pm standard error) for dependent and independent variables measured in 2005 for Mica ($n = 112$) and Youngs Creek ($n = 130$). Variables were compared between streams using ANOVA. Results for significance of $P < 0.001$ are denoted with an asterisk (*).

Variable	Mica Creek	Youngs Creek	ANOVA
Tadpole Biomass (g/m ²)	1.98 (0.27)	1.67 (0.24)	No difference
Tadpole Density (#/m ²)	3.08 (0.45)	2.35 (0.32)	No difference
Chlorophyll- <i>a</i> (g/m ²)	0.012 (0.001)	0.002 (0.0004)	*
AFDM (g/m ²)	12.73 (1.33)	3.93 (0.06)	*
Aspect (°South)	129.12 (3.37)	109.89 (4.26)	*
Temp Water (°C)	10.98 (0.27)	10.60 (0.21)	No difference
Temp Air (°C)	20.11 (0.40)	17.27 (0.46)	*
Stream Discharge (m ³ /s)	0.37 (0.04)	0.94 (0.07)	*
Width/Depth	23.80 (1.30)	26.56 (1.58)	No difference
Area (m ²)	2.57 (0.18)	5.42 (0.31)	*

Table 3. Tadpole and periphyton results for Young and Mica creek from the summer field sampling of 2005.

Sampled Units	Mica Creek	Youngs Creek
Transects sampled	120	135
Reaches sampled	24	27
Rocks sampled for periphyton	70	80
Egg masses (eggs) observed	3 (433)	2 (182)
Tadpoles captured	737	1,399
Transects w/ tadpoles (% total)	80 (69%)	99 (76%)
Adults captured	66	15

Table 4. Tadpole and fish occurrence results at the transect and reach (in parentheses) scale for Youngs and Mica creek from summer field sampling of 2005.

Youngs Creek	Fish Absent	Fish Present
Tadpoles Absent	26 (1)	5 (0)
Tadpole Present	85 (15)	14 (10)
Mica Creek		
Tadpoles Absent	26 (2)	10 (2)
Tadpole Present	29 (2)	50 (18)

FIGURES

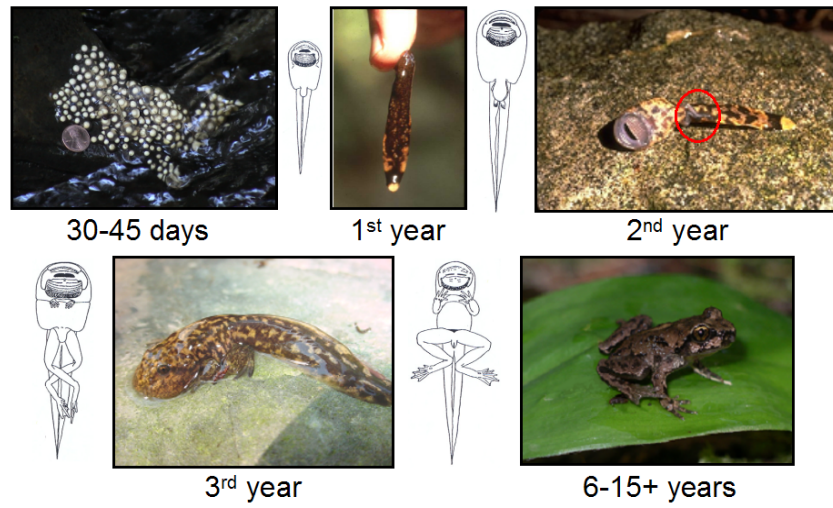


Figure 1. Age class structure of *Ascaphus* spp. Eggs development generally extends from 30-45 days. First year tadpoles lack functional limbs, which appear during the second year (red circle). Development of forelimbs occurs by the third year, when metamorphosis is completed. Following metamorphosis, sexual maturation may require an additional three years (drawings adapted from Metter 1964).



Figure 2. Age classes of *A. montanus* tadpoles captured in the Mica and Youngs creek watershed from 06/29/05 to 08/02/05. Photo from left to right (w/ total number of animals per age class captured during 2005) included: 1st year (Mica: 365; Youngs: 481), 2nd year (Mica: 190; Youngs: 552), and 3rd year animals (Mica: 159; Youngs: 366) undergoing three distinct developmental stages in metamorphosis. Photo taken by Jason L. Jones.

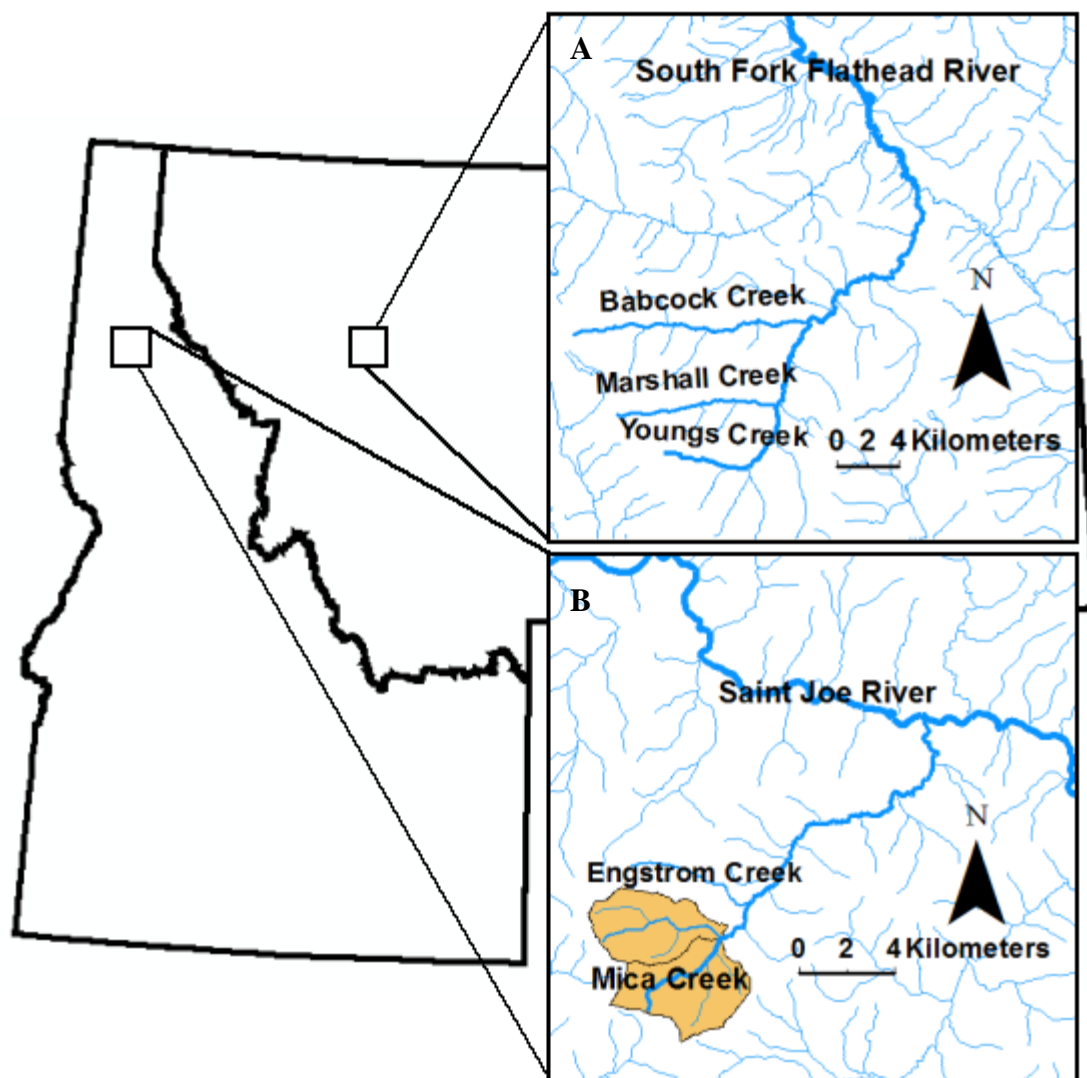


Figure 3. Study sites: A) Youngs Creek, headwater of the South Fork of the Flathead River, Bob Marshall Wilderness Area, Montana; B) Mica Creek (Experimental Watershed portion shaded), tributary of the St. Joe River, Idaho.

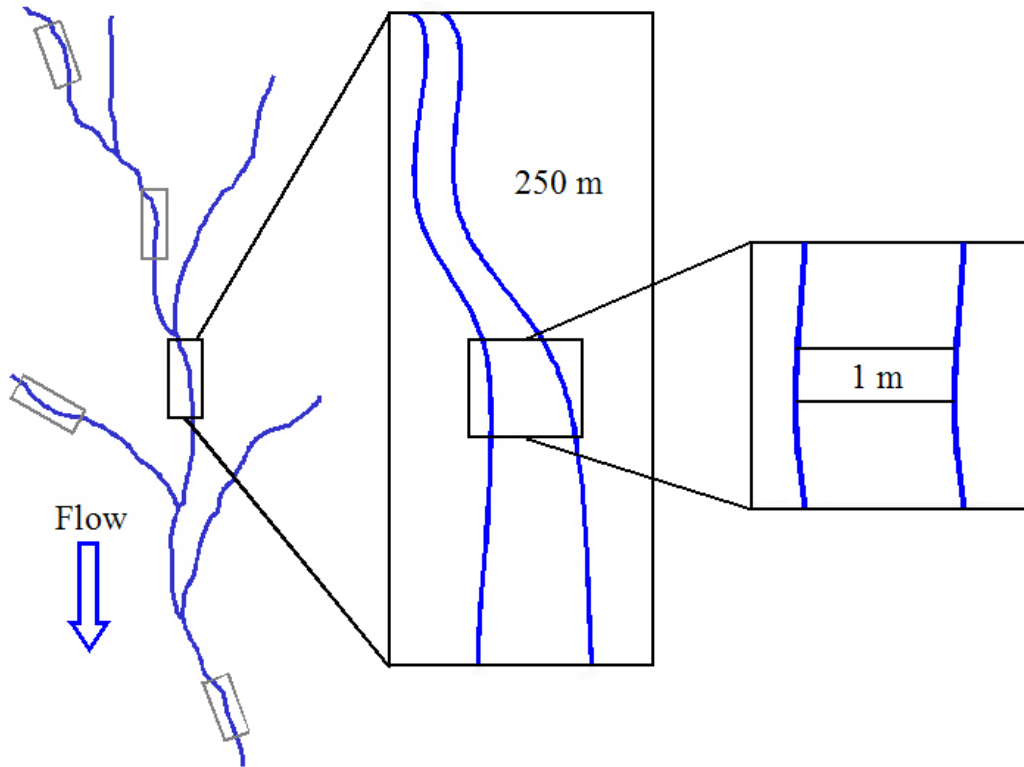


Figure 4. Our sampling design in a theoretical stream network. Each small box in the stream represents a stream reach (250 m in length). Based on geographical, biological, and logistical rationale, we designated stream reaches. Within each reach, we sampled five transect belts (1 m in length). In each belt we measured tailed frog density and biomass and physical habitat features, in addition to noting fish occurrence.



Figure 5. Illustrations of habitat and tailed frog sampling procedure. a) Measurements of physical stream characteristics were taken at each 1m transect. b) Tailed frog tadpoles were sampled by working upstream of two handheld D-frame nets (0.8mm mesh). c) Each transect was sampled by lifting or removing large cover items and kicking through the substrate.



Figure 6. *Ascaphus montanus* eggs found near Flume 3 in Mica Creek 7/5/05 (left). Right photo depicts the same egg mass 24 days later, 07/29/05. Photo taken by Jason L. Jones.



Figure 7. Brook trout (*Salvelinus fontinalis*) eating an adult *A. montanus* in west fork Mica Creek. Two predation events were witnessed and documented within Mica Creek. Photo taken by Jason L. Jones.

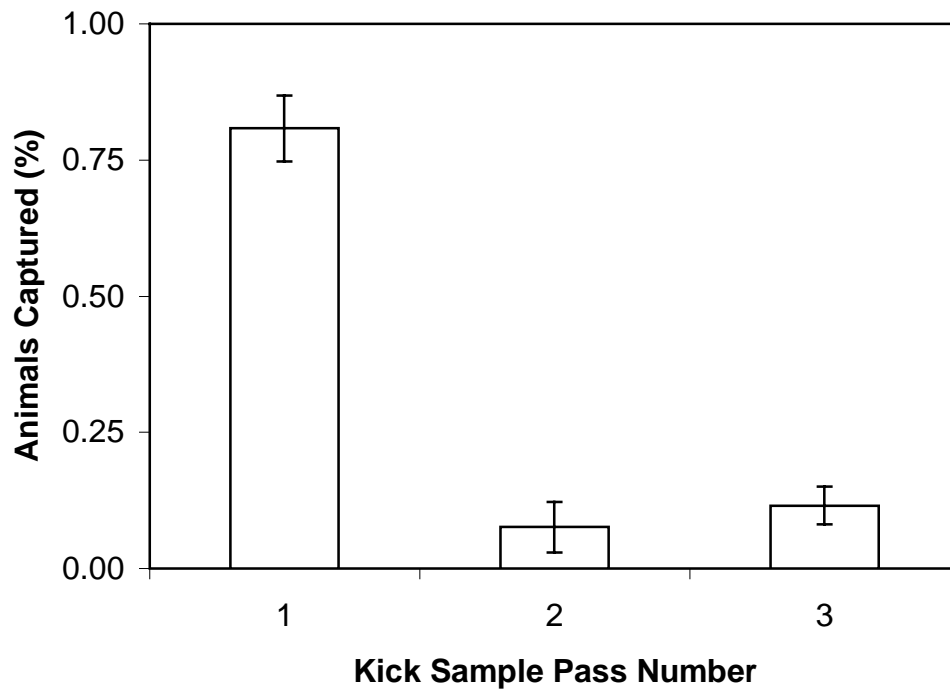


Figure 8. 1st pass was significantly more effective in removing amphibians than subsequent passes. The efficiency of the first pass averaged 80.8% (N = 11, DF = 9, $r^2 = 0.96$, $p < 0.001$).

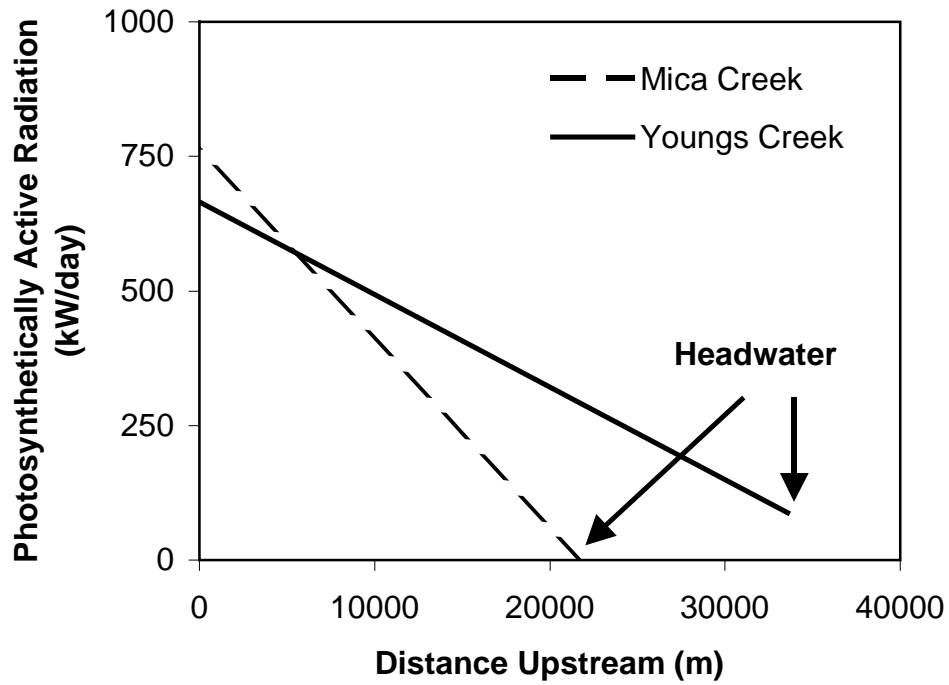


Figure 9. The relationship between photosynthetically active radiation (PAR; kW/day) and distance upstream (m) for Youngs and Mica creek. The headwater of each stream is delineated in the graph with arrows. Both streams exhibited a decreasing trend in PAR levels with upstream distance (Youngs: $y = -0.0172x + 665.4$; $r^2 = 0.707$, $P = 0.018$; Mica: $y = -0.0347x + 758.4$; $r^2 = 0.462$, $P < 0.021$).

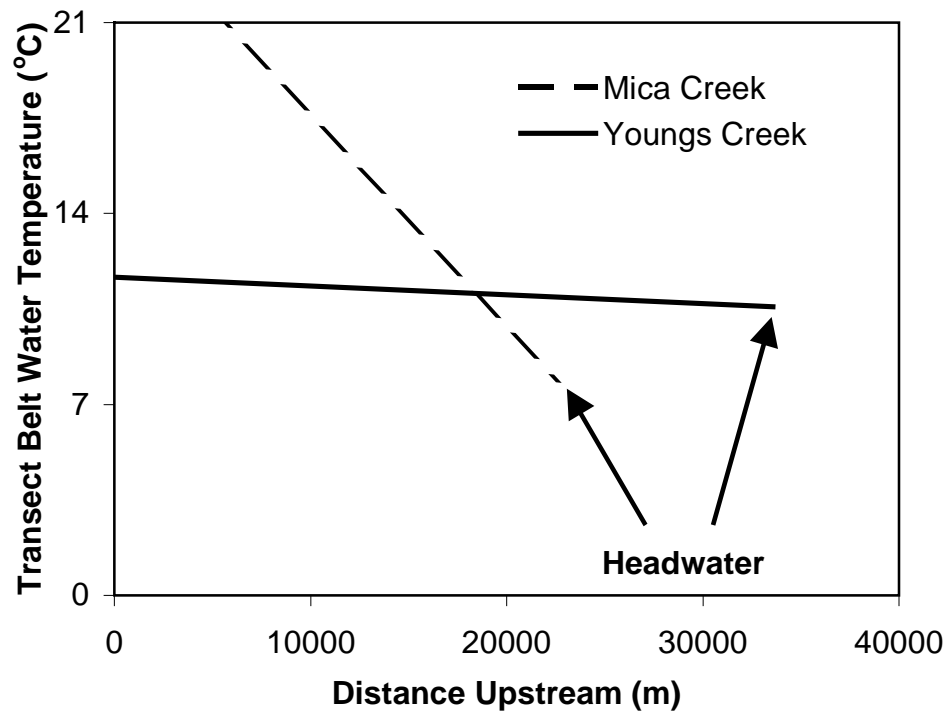


Figure 10. The relationship between each transect belt's water temperature (°C) and distance upstream (m). (Youngs: $y = -3\text{E-}05x + 11.674$, $R^2 = 0.0161$, $P = 0.03$; Mica: $y = -0.0008x + 25.182$ $R^2 = 0.6788$, $P < 0.001$)

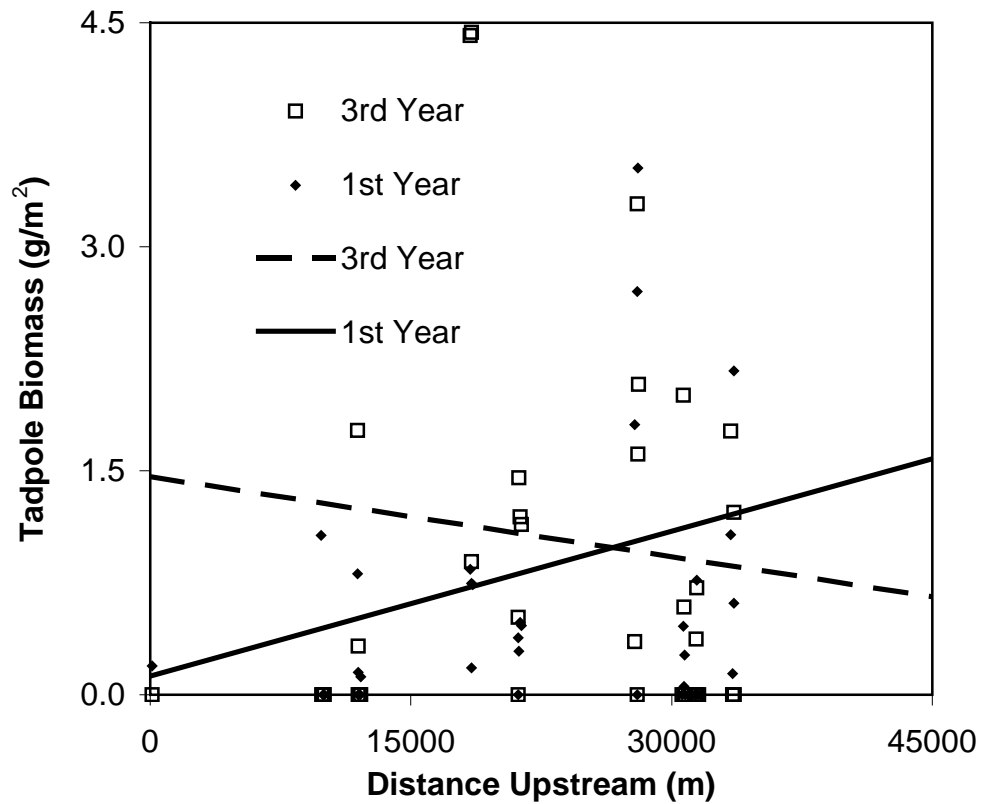


Figure 11. Tadpole age class distribution in Youngs Creek. Biomass varied along the stream network with age class, 1st year tadpoles occurred in higher abundance higher upstream, while 3rd year tadpoles were observed in higher abundance in downstream reaches (1st year: $y = 3\text{E-}05x + 0.1262$; $r^2 = 0.045$, $P < 0.0001$; 3rd year: $y = -2\text{E-}05x + 1.4617$; $r^2 = 0.012$, $P = 0.641$).

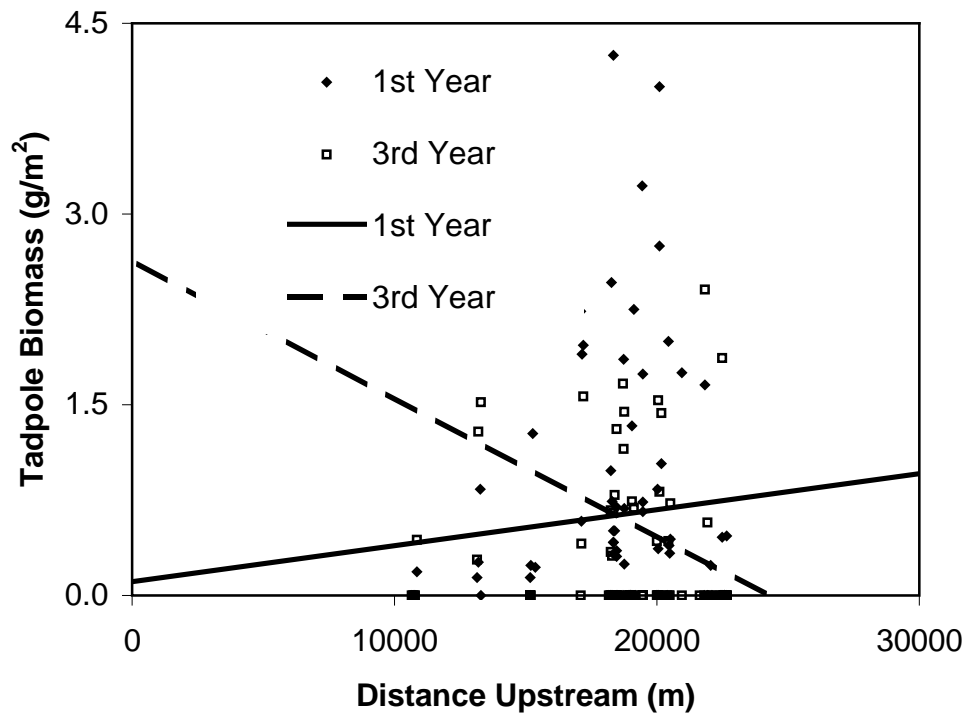


Figure 12. Tadpole age class distribution in Mica Creek. Similar to Youngs Creek, biomass varied along the stream network with age class, 1st year tadpoles occurred in higher abundance higher upstream, while 3rd year tadpoles were observed in higher abundance in downstream reaches (1st year: $y = 3\text{E-}05x + 0.1071$; $r^2 = 0.007$, $P = 0.076$; 3rd year: $y = -0.0001x + 2.6386$; $r^2 = 0.045$, $P = 0.049$).

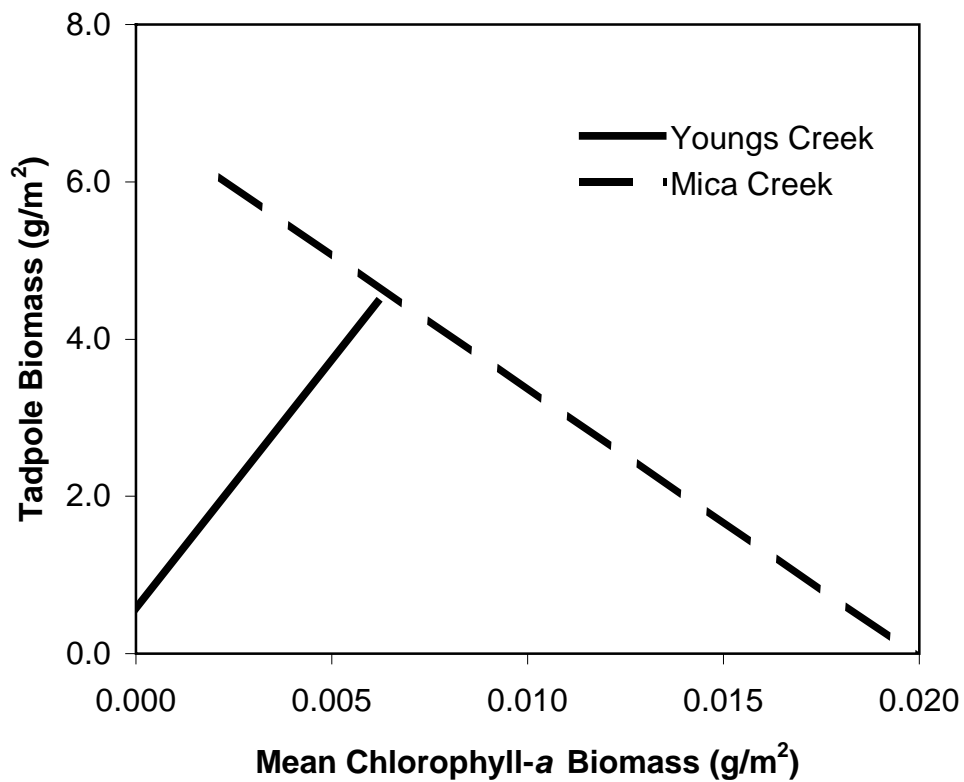


Figure 13. Mean chlorophyll-*a* as a predictor variable for tadpole biomass. Chlorophyll-*a* values varied by an order of magnitude between Youngs and Mica Creek. Relationships between food and tadpole biomass appeared in both streams, but the influence of chlorophyll-*a* changed from positive (Youngs) to negative (Mica) (Youngs: $y = 632.26x + 0.5756$; $r^2 = 0.187$ $P = 0.132$; Mica: $y = -344.83x + 6.8295$; $r^2 = 0.298$, $P = 0.021$).

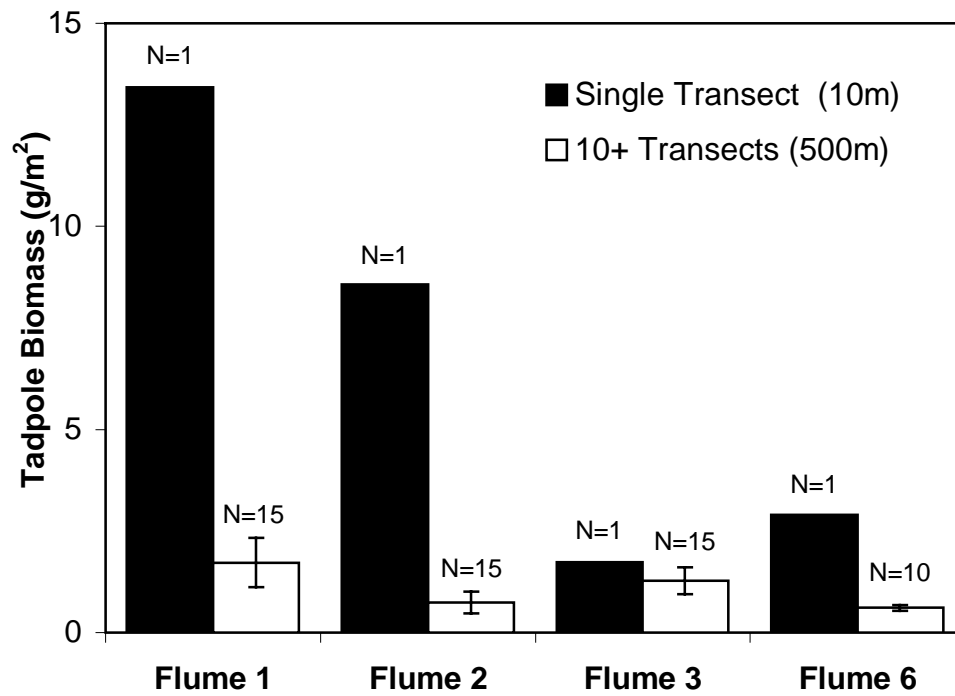


Figure 14. The comparison of two sampling designs in the Mica Creek experimental watershed. A single 10 m transect belt in all cases exceeded the biomass (shown here) and density (not shown) estimates of multiple (≥ 10) transect belts randomly placed 500-1000 m above the treatment or control flume.

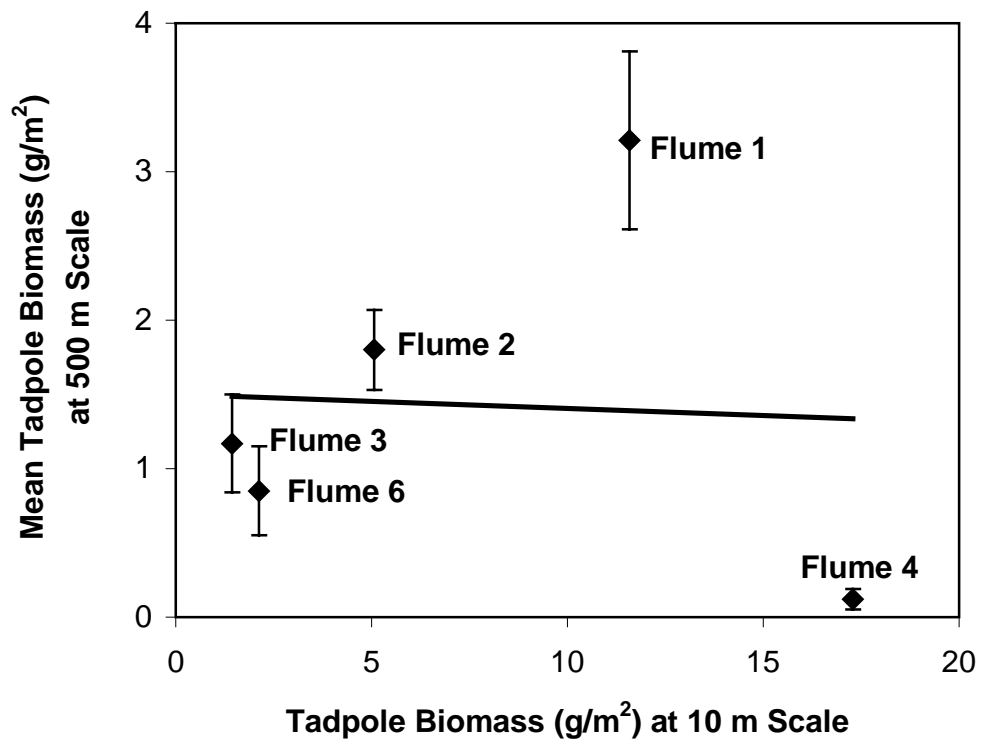


Figure 15. The comparison between two sampling designs at each flume in Mica Creek experimental watershed. Variation between sampling designs appears to be related to spatial scale. The equation describing the line equals: $y = -0.0096x + 1.5018$ ($r^2 = 0.003$; $P = 0.665$)

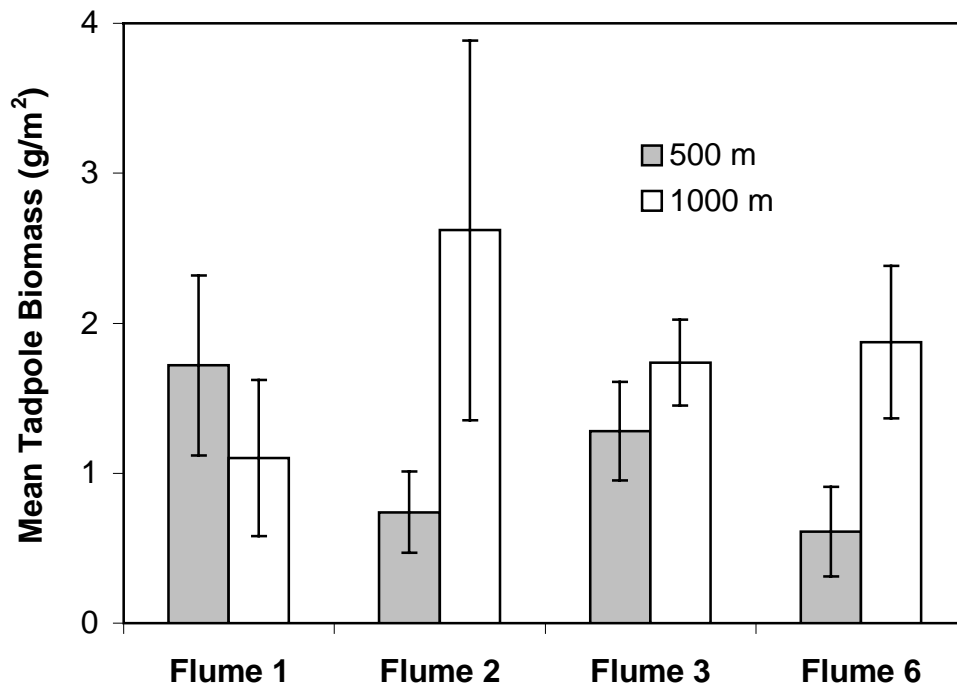


Figure 16. Three of the four sites sampled in Mica Creek experimental watershed that used randomly placed 1 m transect belts were not significantly different in their mean tadpole biomass (ANOVA: $P > 0.12$) and density (). 10 transect belts randomly placed across 1,000 m resulted in a significantly higher mean tadpole biomass than 15 transect belts across 500 m of stream above flume 6 (ANOVA: $P = 0.02$).

APPENDIX A:

Aspect (°)	Record the direction of water flow at downstream edge of transect using a magnetic compass, in relation to true north, not magnetic. Conversion to degrees from south will allow for statistical comparisons.
Water temperature (°C)	Record the thalweg temperature at downstream edge of transect.
Air temperature (°C)	Record air temperature at 1 meter height on bank in the shade.
Gradient	Stream gradient will be measured using digital elevation models (DEM) in a GIS.
Survey width (cm)	Width of the stream transect to be surveyed; this is generally the wetted width with few exceptions (wetted depth will be recorded in those instances). Width will be used in calculation of the density and biomass of amphibians captured.
Wet depth (cm)	Record the stream depth at three locations (generally dividing the stream into thirds working left to right while oriented upstream): right bank, thalweg, and left bank.
Flow (m/s)	Using submersible fishing bobber and line, bobber is filled until buoyant and placed in the thalweg. Record the time it takes to travel 1m from upstream edge to downstream edge of transect (repeated three times).
Substrate (mm)	Substrate is classified into 2 categories (dominant and subdominant) based on substrate sizes from modified Platts et al. (1983). Classes include: silt, <1mm, 1-2mm, 2-4mm, 4-8mm, 8-16mm, 16-32mm, 32-64mm, 64-160mm, 161-256mm, >256. Non-rock materials are given classes: wood, bark, soil, vegetation, leaf litter. Moving along the downstream edge, 10cm x 30cm view boxes will be used to estimate dominant and subdominant substrate percentages.
Pebble counts (%)	A Wolman pebble count will be conducted at each transect. Using the substrate classification system, pebbles (>8mm) will be measured along the intermediate axis. The stream will be visually divided into thirds, moving from left to right, ten pebbles will be measured in each third.
Substrate embeddedness (%)	Estimation of embeddedness occurs during the pebble count. The degree of embeddedness is recorded as the percent of the pebble covered in fine sediment (<2mm); percentages are divided into categories: 0-5%, 5-25%, 25-50%, 50-75%, 75-100%.
Substrate anchor	Following amphibian surveys, estimate how cemented larger substrate particles are within the transect (>9mm). The categories include: no resistance, slight pull dislodges particles, particles unmovable or move with significant effort.

Large woody Debris (%)	Estimate the entire transect covered by in-stream large woody debris (woody debris measuring >5mm diameter) using categorical percentages: 0-5%, 5-25%, 25-50%, 50-75%, 75-100%.
Organic debris (%)	Estimate the percent of the entire transect area covered by in-stream organic debris (<5mm diameter wood and leaf litter) using categorical percentages: 0-5%, 5-25%, 25-50%, 50-75%, 75-100%.
Undercut bank (%)	Estimate the percent of the entire transect that extends into and is covered by an undercut bank using categorical percentages: 0-5%, 5-25%, 25-50%, 50-75%, 75-100%.
Cover (%):	Using a Solar Pathfinder at sites sampled for periphyton, estimate the percent of the entire transect area that has overhanging vegetation or other shading cover.
Reach classification	Describe the stream reach classification of the transect using the categories: pool, cascade, high gradient riffle, low gradient riffle, glide.
Debris volume (L)	Following amphibian surveys, record total volume of debris accumulated in the kick nets during kick-sampling.
Debris composition	Record the dominant and subdominant debris type found in the kick nets after kick-sampling using categories described under substrate.

APPENDIX B:

Voucher specimens taken in Mica Creek, summer 2006. Coordinate data was recorded in UTM's and map datum in NAD27.

Species	Life Stage	Number	UTM Easting (m)	UTM Northing (m)
<i>Ascaphus montanus</i>	Tadpole	15	557356	5223845
<i>Ascaphus montanus</i>	Juvenile	1	557356	5223845